New Materials for Photon - Electron Conversion
A Model for Theory Inspired Discovery in MS

LDRD suggestion for M2D2 initiative

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List of names is not complete!

Investigating independent LDRD under X-ray Science

Goals of LDRD: Creating Workforce and Infrastructure allowing the Development of Novel Materials and Meta-Materials with Specific Functionality

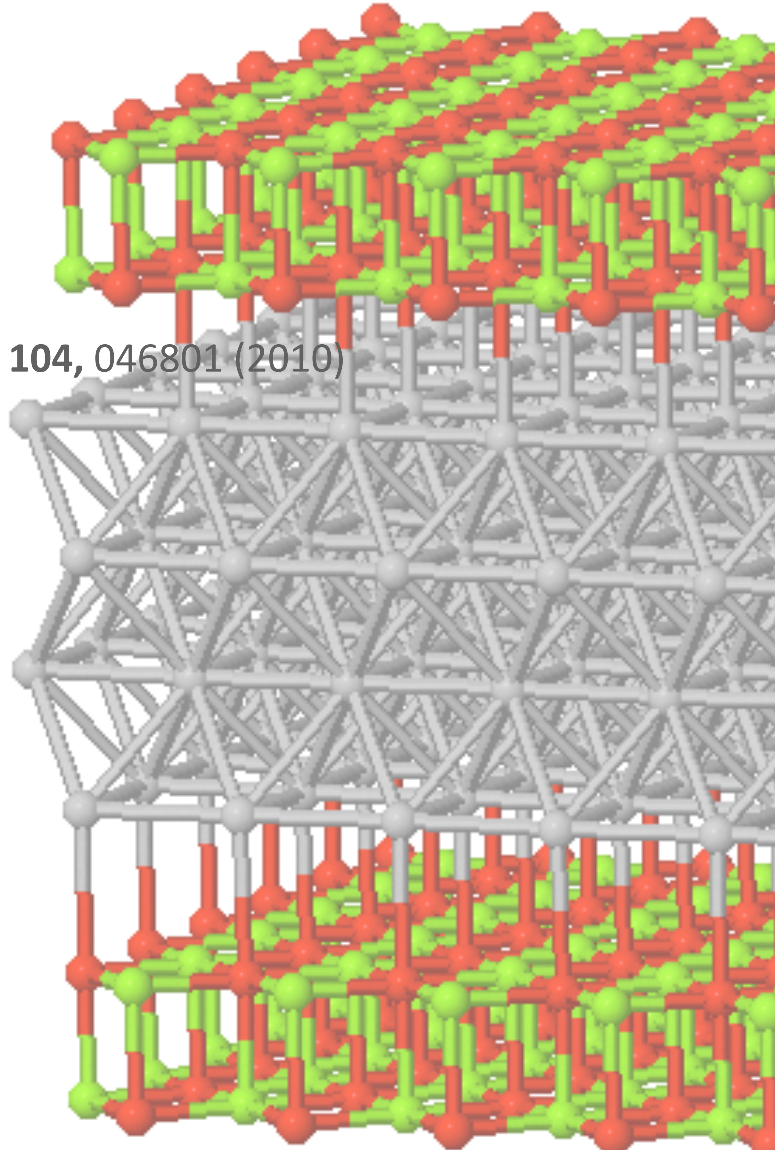
Existing device development tools are based on university developed simulation tools

- Establishing a group of people who can perform the cycle of rational design:
  - Simulation: description of the functionality of the material (like I-V curve) but also processing parameter ("foundry-simulation" like: on-smart-cut, SOI [Silicon-on-Insulator], SON [Silicon-on-nothing - the new Toshiba idea]),
  - Theory: calculation of band-structure/band-engineering, Fermi-level pinning….,
  - Growth,
  - Characterization: both functionality as well as microscopic composition, electronic and structure.
- Creating missing lab infrastructure and utilizing existing tools:
  - Igor's & Richard Rosenberg's Tools
  - CNM? (UHV STM/AFM)
  - APS and hard x-ray tools
  - Using growth facility from LAPPD
  - NIU tools for simulation
  - Growth expertise and equipment from UIUC
  - Data base
- Specific goals:
  - Ultra low emittance
  - Ultra fast response
  - High QE, robust photocathodes, wavelength tunability

Impact, Relevance, and Importance

- Impact
  - Enabling technology for next generation electron accelerators
  - Novel pico-second (or faster) electron sources for electronics in THz range (very energy efficient) and ultrafast electron microscopy
  - Novel single photon detection concepts using fully integrated technology: extreme spatial resolution (~100-10nm?)
  - Ultrafast X-ray detectors (1ps and faster) with high efficiency at high energies
- Relevance
  - Design of support materials for catalytic nano-particles (enhancing significant catalytic efficiency)
  - Anode optimization in organic solar cells (Graetzel cell)
  - Optimization of hybrid solar cells (plasmon enhanced absorption)
  - “conventional” complex oxides (superconducting devices, ferro-electrics, high dielectrics…)
- Importance
  - Strengthen Illinois by combining strength of ANL, IIT, NIU, and UIUC.

Specific Example and Starting Point: MgO/Ag low emittance cathode



- Strength
  - Motivated by catalysis research
  - Tuning band structure to create cold emitting electrons
  - Theoretical work is "approved and accepted": Phys. Rev. Lett. **104,** 046801 (2010)
  - Would solve an important problem for accelerator if possible
- Challenge:
  - Establish growth and characterization
  - Experimentally prove
  - Demonstration of full development circle is possible
  - Project is well defined
- Correlation with Outside Activity:
  - BNL/Berkley will focus on optimization of existing materials
  - ANL will focus on Novel Structures and meta-materials
- Negative:
  - Project is based on old LDRD

Specific Example 2 and Starting Point: Photocathode Accelerator Test Facility

Strength

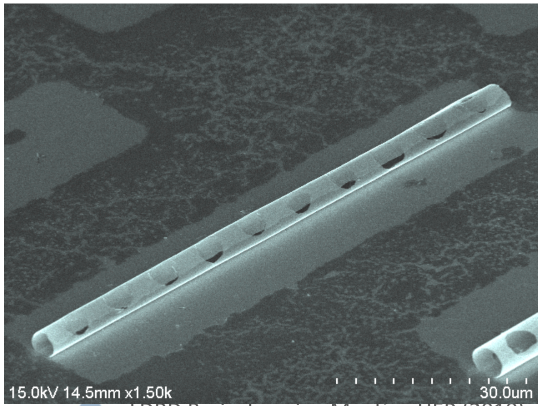
- An important "characterization tool"
- Provide a "proof-in-the-pudding" test for photocathodes under realistic accelerator conditions
- Able to test new and a variety of photocathodes for accelerators
- Photoinjector gun is already available – ½ cell gun
- Part of the "experimental area" facility in the AWA expansion plan
- Project will involve a (i) study of the compatibility between the fabrication/characterization network and the existing photoinjector gun, (ii) redesign of the photoinjector gun, (iii) a design for a suitable vacuum transfer, and (iv) modification to the photoinjector gun*.

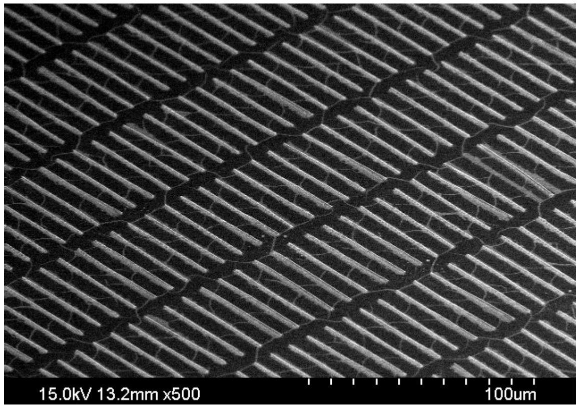
Negative

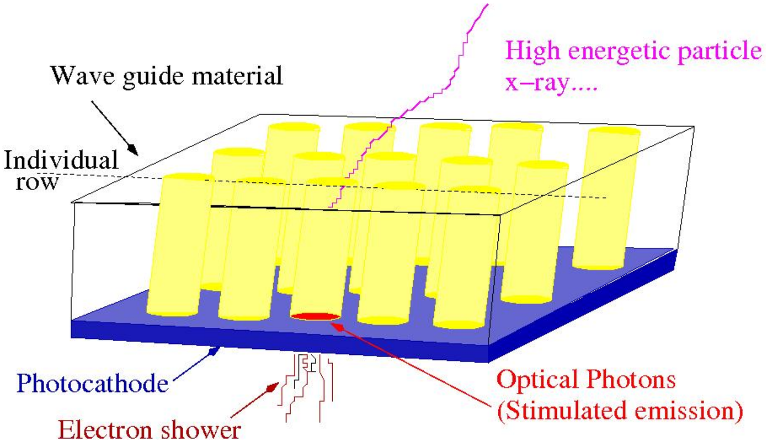
- *Dependent on the AWA expansion plan and timetable
- Compatibility between fabrication system and existing photoinjector gun might be a challenge.

“Crazy Idea”: Light Amplification before Photon-Electron conversion

- Basic idea: Creating a three dimensional structure which includes a laser medium and a cathode structure
- Advantage:
  - Optical gain between 20 and 100
  - Wavelength adjustment of cathode and laser-medium by QW structures
  - High time resolution even with thick absorber material (x-rays)
  - Optimum cathode/laser-emission optimization
  - Fast switch on/off time
- Challenge:
  - Complex integration of nano electronics with detection electronics
  - Example for extreme complex meta-materials







Cost and Efforts

Proposal Development:
Accelerator & Meta-Materials

	Year 1	Year 2	Year 3
▪ Basic costs (infrastructure):			
– Theory postdoc:	$90K	$90K	$90K
– Simulation Effort:	$50K	$50K	$50K
– Costs for compatibility upgrades	$100K	-	-
– Including critical characterization tool (SIMS, SEM)	$150K	$200K	-
▪ Specific cost MgO/Ag:			
– Effort	$120K	$120K	$120K
– M&S	$100K	$100K	$50K
▪ Specific cost light-amplified photocathode:			
– Postdoc (UIUC)	$84K	$84K	$84K
– Clean room & M&S	$100K	$100K	$50K
▪ Total:	~$800K	$700K	$450

Conclusions

- Goals:
  - Creating network of collaboration partners (Theory, Simulation, Growth, Characterization)
  - Creating infrastructure which makes synergetic use of existing tools possible (including CNM, APS, lab based tools, computer facilities)
  - Creating data base for materials, processes,…..
  - Preparing the team to be compatible for DOE call on meta-materials
- Approach:
  - Creating infrastructure which can be used by everybody in the laboratory
  - Installing of necessary procedures for successful interactions (Theory, Simulation, Growth, Characterization)
  - Demonstration of successful work on the example of the two cathode examples
- Cost:
  - Total over 3 years: $1.95M
  - Proposal development within year 2: start of possible pay-back in year 3?